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Assessing the Sustainability of Selective Logging in Ankarabolava-Agnakatrika New Protected Area

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Abstract:

Over the past 50 years, more than 90% of dense low-altitude humid forest in the District of Vangaindrano has been lost to deforestation and the remaining fragments continue to be threatened by slash and burn agriculture and selective cutting by local populations. These activities are driven by widespread poverty, population growth, and lack of development, which have made subsistence increasingly difficult. This study investigates logging rates and the stock of five commercially valuable trees in the Ankarabolava-Agnakatrika New Protected Area. Fifteen 1000m^2 transects were established systematically within the territory of the Matanga commune. Within each transect data was collected on all trees cut in the past year and demographic information was collected on five of the most commercially valuable species. Results showed that extensive illegal logging is taking place and the rates of loss for target species were as high as 40% in the past year. The five target species are already devastated among larger size classes and if current rates of logging continue, it is likely the forest will disappear in the near future.

Introduction:

Madagascar is a country rich in biodiversity and other forms of natural capital yet it remains extremely poor (World Bank, 2015). According to the World Bank's Systematic Country Diagnostic, as of 2012, 91.2% of the population of Madagascar was living beneath the international poverty line ($2 purchasing power parity per capita per day) and 78.2% was living in extreme poverty ($1.25 purchasing power parity per capita per day) (World Bank, 2015). Rural populations often have poverty rates twice as high as urban areas and the southeast of Madagascar is especially poor with 73-89% of the population living in extreme poverty (World Bank, 2015). Unfortunately, in many parts of Madagascar, necessity and lack of alternatives drive the unsustainable use of forest resources for agriculture or for sale, which diminishes natural capital and further restricts economic opportunities for the future.

This study took place in the Ankarabolava-Agnakatrika Protected Area located in the District of Vangaindrano and the region of Atsimo-Antsinanana. Ankarabolava-Agnakatrika is a new protected area created as part of the Durban Vision and managed jointly by the American NGO, Missouri Botanical Garden (MBG) and local communities. According to Humbert's phytogeographical classifications the forest is classified as evergreen low-altitude dense humid forest (MBG, 2015). It is estimated that this forest covered 30,000 ha as recently as the 1950s, but is now limited to only 1577 ha (MBG, 2015). Without effective conservation, the forest may disappear completely in the next few decades (MBG, 2015). Now, the largest remaining forest fragment in the Vangaindrano District, Ankarabolava-Agnakatrika plays an important role both ecologically and economically (MBG 2015).

MBG's initial floristic inventory revealed that Ankarabolava-Agnakatrika contains 283 plant species representing 77 families. This includes 4 local endemics, 11 IUCN Red List species, and many rare species (MBG, 2015). Ankarabolava-Agnakatrika is also the source of the river Masianaka, which provides water to much of the region (MBG, 2015).

The protected area is home to 35 families and provides firewood, construction materials, medicinal plants and supplementary food to many more (MBG, 2015). It also provides an important source of income through the sale of logs, planks and beams. The forest is also a source for new lands for *tavy,* a method of land conversion which involves cutting all the trees in a section of forest and then burning it to create new land for agriculture.

In Madagascar, all forest belongs to the state and all deforestation is illegal (Ferguson, 2010). Despite this both *tavy* and small-scale selective logging are widespread. However, as part of the *Systeme de Nouvelles Aires Protegées*, many community-managed forests have been established (Ferguson, 2010). These allow for both conservation and limited sustainable use (Assemblée Nationale, 2015). Typically they are divided into a strict conservation zone (*le noyau dur*) and a buffer zone (*le zone tampon*). This buffer zone consists of controlled occupation zones (*le zone d'occupation controllée*) and sustainable use zones (*le zone d'utilisation durable*).

Ankarabolava-Agnakatrika Protected Area is divided into two fragments – Ankarabolava to the south and Agnakatrika to the north. I limited my study area to only the northern part of the Ankarabolava forest, which belongs to the commune of Matanga, and is comprised completely of *Zone Tampon*. Traditional rights to and management of Ankarabolava is split between two communes – Matanga and Vohipaho. Each commune manages their section of the forest through their *Komity Dina (Kodina)* in partnership with MBG. Traditionally, a *dina* is a set of social norms and customs created and enforced by the community (Andriamalala and Gardner, 2010). However, many conservation organizations have created *dina* in collaboration with local communities in order to regulate natural resource use (Andriamalala and Gardner, 2010). For conservation *dina*, the *Kodina*'s duties include issuing permits to cut a limited number of trees within the sustainable use zone and implementing fines for those caught cutting illegally. However, it is difficult to determine what levels of cutting are sustainable because there has not yet been a stock assessment of trees within Ankarabolava. This study should begin to close this key knowledge gap by providing information on the population of five key commercial species and a preliminary inventory of the species cut in the forest and the frequency at which they are cut.

Methods:

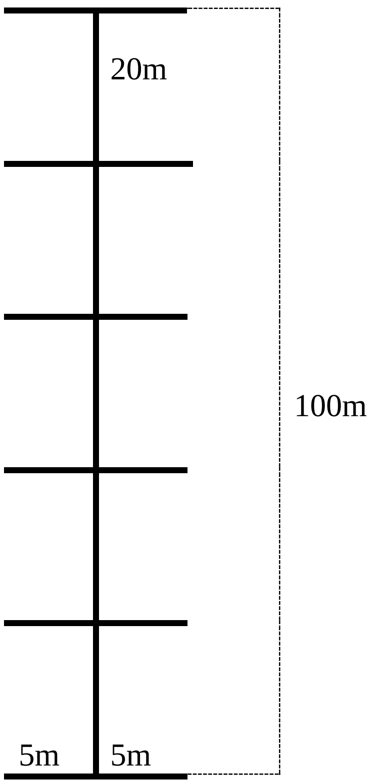
In order to assess the stock of commercially valuable wood and the sustainability of selective cutting, I collected data on current populations of commercially valuable trees and on trees cut within the past year.

I surveyed 15 1000 m2 transects (Figure 1). Each was 10mx100m and oriented from south to north. Transect locations were selected to cover the fragmented landscape as evenly as possible. Due to the fragmented nature of the forest this was completed by visual estimation using satellite imagery from Google Earth. Coordinates were obtained for each plot using Google Earth and located with a Garmin *GPSmap 62*.

Figure 1: The yellow-green section represents the sustainable use zone and the red section represents the zone of controlled occupation. The bright green polygon at the southern section marks the boundary of the Matanga section and the boundary of my study area (MBG 2015)

Transects were divided into five 20mx10m sections (Figure 2) to ensure complete coverage and facilitate navigation through dense undergrowth. Orientation was determined using a compass and waypoints were taken to mark the beginning and end of each section to check the accuracy of the size and orientation of the plots. However, it is difficult to determine whether deviations come from human error versus varying accuracy of GPS positions. Notes were taken for each plot on aspect, levels of disturbance, and any significant features included in the plot such as *tavy* zones, trails, and streams.

Figure 2: 10x100m plot set up, divided into five 10x20m sections



Due to time constraints, I limited my population density estimates to 5 species identified by a previous study as the most desirable or useful to local communities (Andrianantenaina, 2010). The 5 species are Voapaky (*Uapaca littoralis*), Aveotry (*Hartogiopsis trilobocarpa*), Haziny (*Symphonia fasciculata*), Lalo (*Weinmannia venusta*), and Taimbarika (*Cleisthanthus sp*.). *Uapaca littoralis* is immediately identifiable by its distinctive aerial roots. It also has large obovate leaves with a yellow midrib and is found in both riparian and upland habitats. *Hartogiopsis trilobocarba* has opposite-lanceolate leaves with serrate margins. Other traits include a reddish trunk in large individuals and ridges on the branches. It is found in upland habitats. Haziny, a riparian species, is notable for the characteristic pattern of branching and for the yellow resin characteristic of the Clusiaceae family. Lalo has pinnately compound opposite leaves. Leaflets are opposite, lighter on the underside, and serrate with a prominent hairy midrib. It is found in riparian environments. Taimbarika has alternate, ovate leaves with acuminate tips and entre margins. It can be distinguished by a central, reddish circle in a cross-section of the wood. My guides identified all species using vernacular names and unfortunately not all of them correlate with a single scientific species, so for simplicity I will use vernacular names throughout the remainder of this paper (for a table of scientific names see Appendix II).

For each living individual of these 5 species with a diameter of 3cm or greater, I measured its diameter at breast height (DBH) and estimated its height. There may be some error introduced to DBH and height because of physical irregularities and human error. For trees with aerial root systems, diameter was measured above the aerial roots sometimes as much as 2-3m off the ground (Figure 3). Cut and resprouted trees were also common and in general if it had been cut in the past year and had sprouts less than 3 cm in size it counted as cut and if it was older and had sprouts 3 cm or greater in size the sprouts were measured. If there were multiple sprouts or a split trunk, DBH and height were taken only for the largest. The most extremely irregular cases (no more than 3 or 4 trees) were excluded from the data set due to difficulty classifying them as either cut or uncut. For example, one tree was still alive but being used as a leg of sawmill and another tree had fallen and resprouted after some of the sprouts were cut. To minimize the effects of possible error, I have grouped them into size classes for much of the analysis. For cut trees 3 cm or greater in diameter, my guides identified if they had been cut in the past year and identified them by their vernacular name. I also recorded diameter for the cut trees. Most trees were cut below breast height so diameter was measured where it was cut. However, buttresses, aerial roots, and new shoots sometimes complicated measurements. Where possible the effects of these were avoided or minimized, but inevitably there is some error.

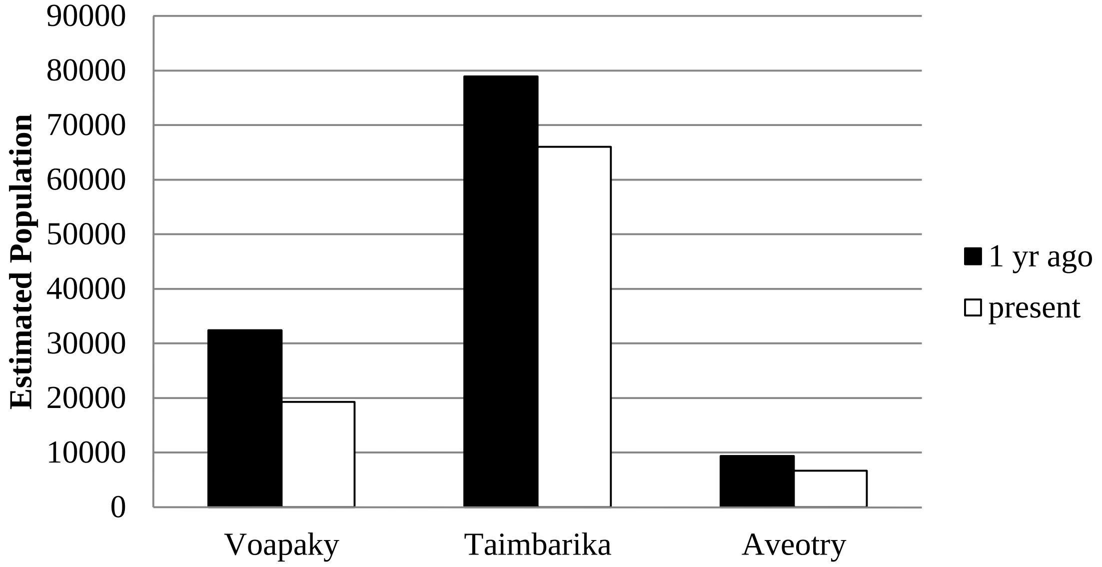
Figure 3: Angela measuring our largest Voapaky (51.4m DBH and 35 m high)

To estimate populations of my 5 target species, I calculated the density per hectare and multiplied that by the forest area of Matanga. Forest area was calculated using Google Earth and found to be approximately 371 ha.

Results:

In total we covered 1.5ha of forest, recording a total 1206 trees representing 66 species. Amongst living trees, we found a density of 52 Voapaky, 18 Aveotry, 178 Taimbarika, 2 Haziny, and 0 Lalo per hectare. Presuming a forest area of 371 ha, this gives us a total current population of 19292 Voapaky, 6678 Aveotry, and 66038 Taimbarika. For Voapaky, Aveotry, and Taimbarika, I estimated the population from 1 year ago by adding together the total number of cut and living trees. Comparing, last year's and this year's population estimates, shows a 40% reduction of Voapaky, 29% reduction in Aveotry, and 16% reduction in Taimbarika populations in the last year alone (Figure 4). Unfortunately, we don't have enough data to accurately extrapolate current populations of Haziny or Lalo, but it is evident that they are very rare in this area of forest.

Figure 4: Change in populations of target species over the last year



Additionally, I found the size distribution of these 3 species was heavily skewed towards diameters of less than 10cm, especially among living trees (Figures 5, 7, 9). Averages for cut trees were a little higher among cut trees. This is probably in part a result of the impossibility of measuring stumps at breast height (130cm). However, larger trees are more valuable and likely under greater pressure. It appears that there is a threshold of about 5cm for all 3 species above which wood is preferred, though we saw some cut even below the 3cm threshold (Figures 6, 8, 10).

Table 1: Average, Maximum, and Standard Deviation of Voapaky, Taimbarika and Aveotry

Species		Average	Maximum	Standard Deviation
Voapaky	Overall	8.95	53	9.60
	Living	7.52	51.4	7.63
	Cut	11.84	53	12.28
Taimbarika	Overall	5.65	37	3.01
	Living	5.40	20.1	2.35
	Cut	7.02	37	5.14
Aveotry	Overall	15.29	42.4	10.61
	Living	16.28	42.4	11.83
	Cut	12.86	25	6.57

<u>Figure 5</u>: Size distribution of Voapaky (*Uapaca littoralis*)

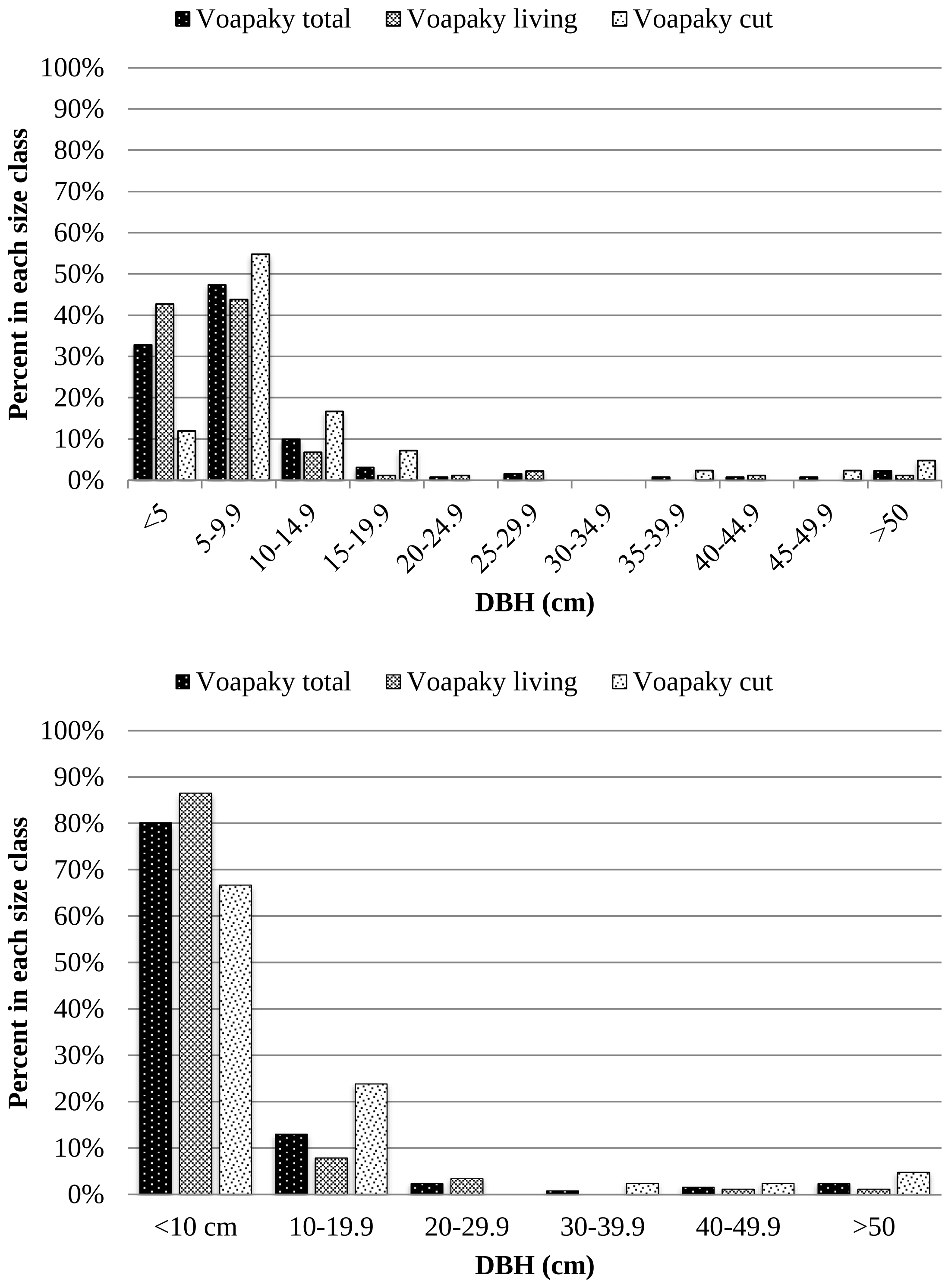
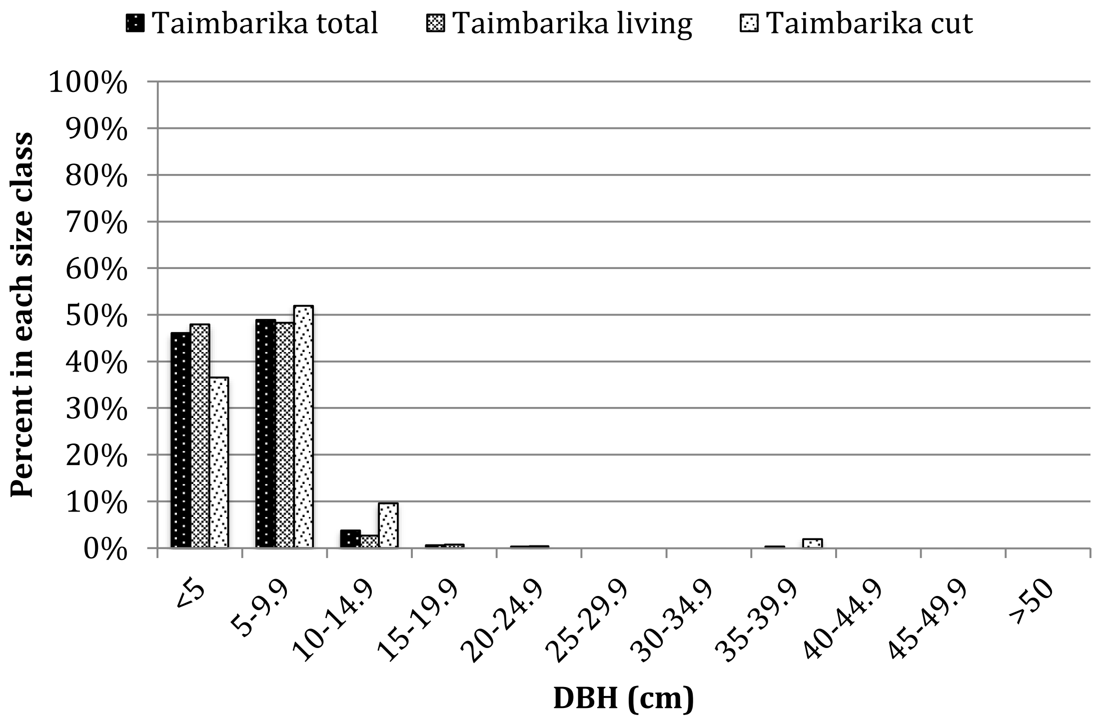


Figure 6: Size distribution of Taimbarika (*Cleisthanthus sp.*)



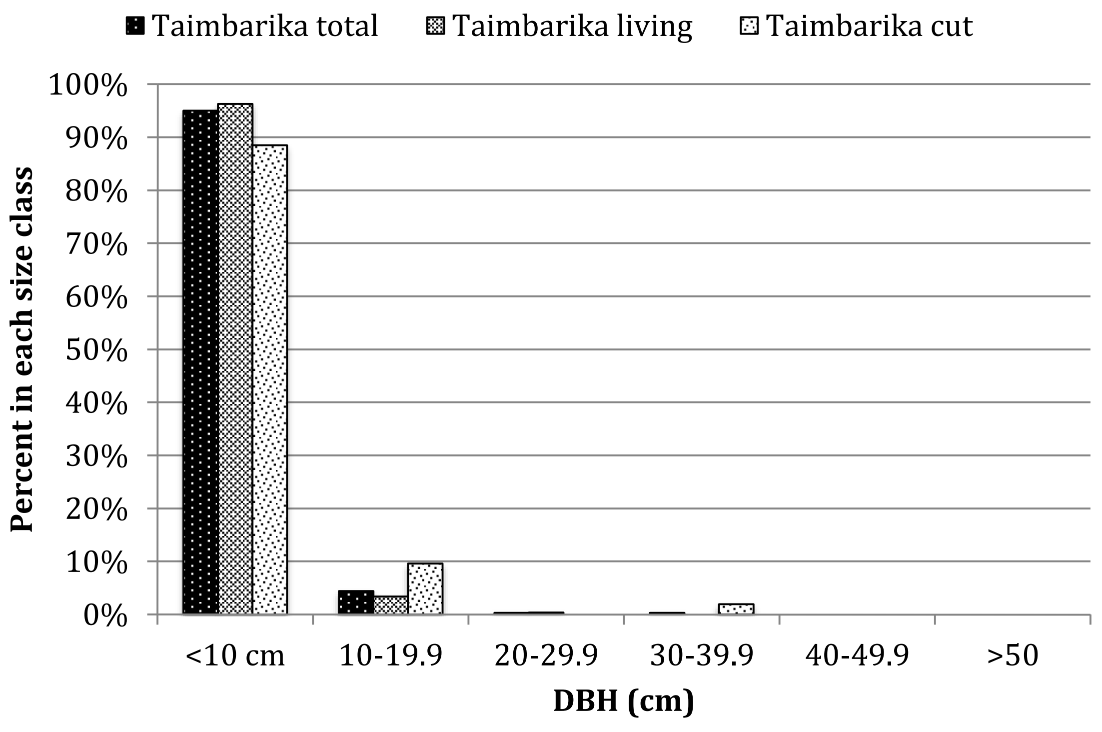
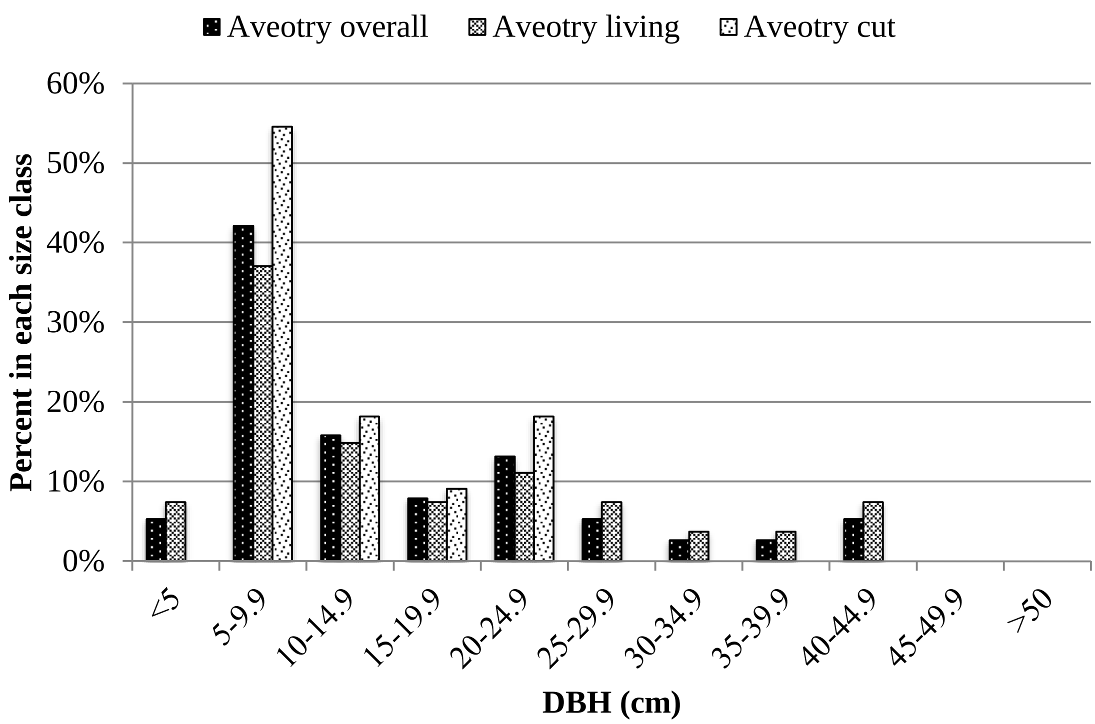
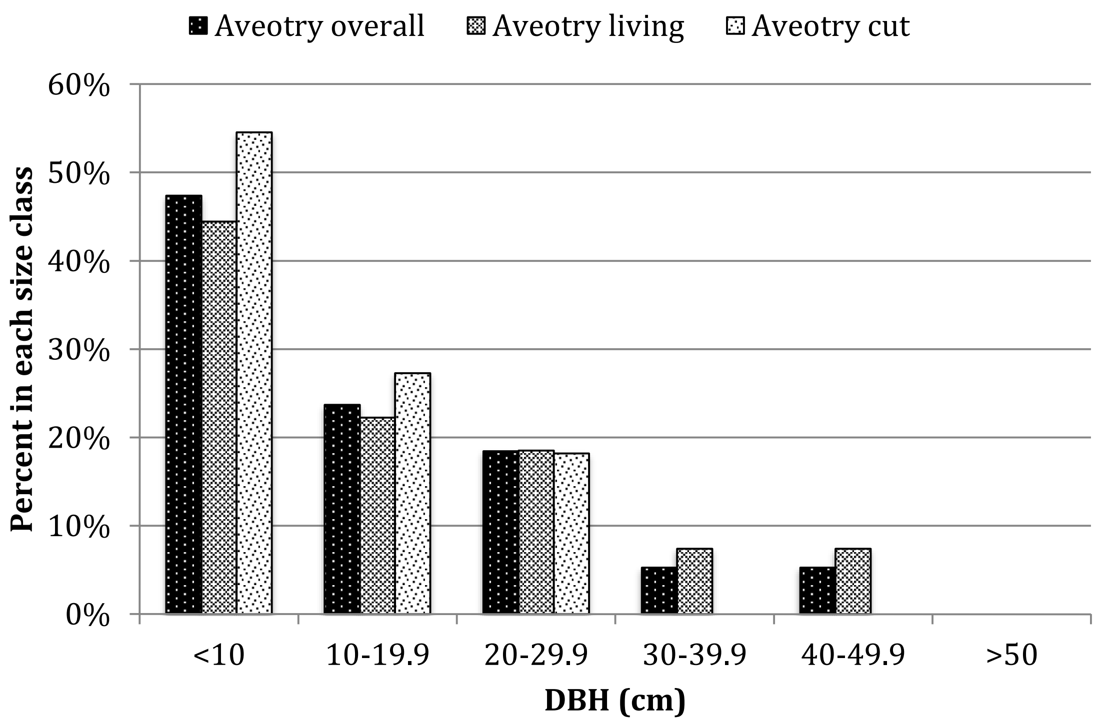


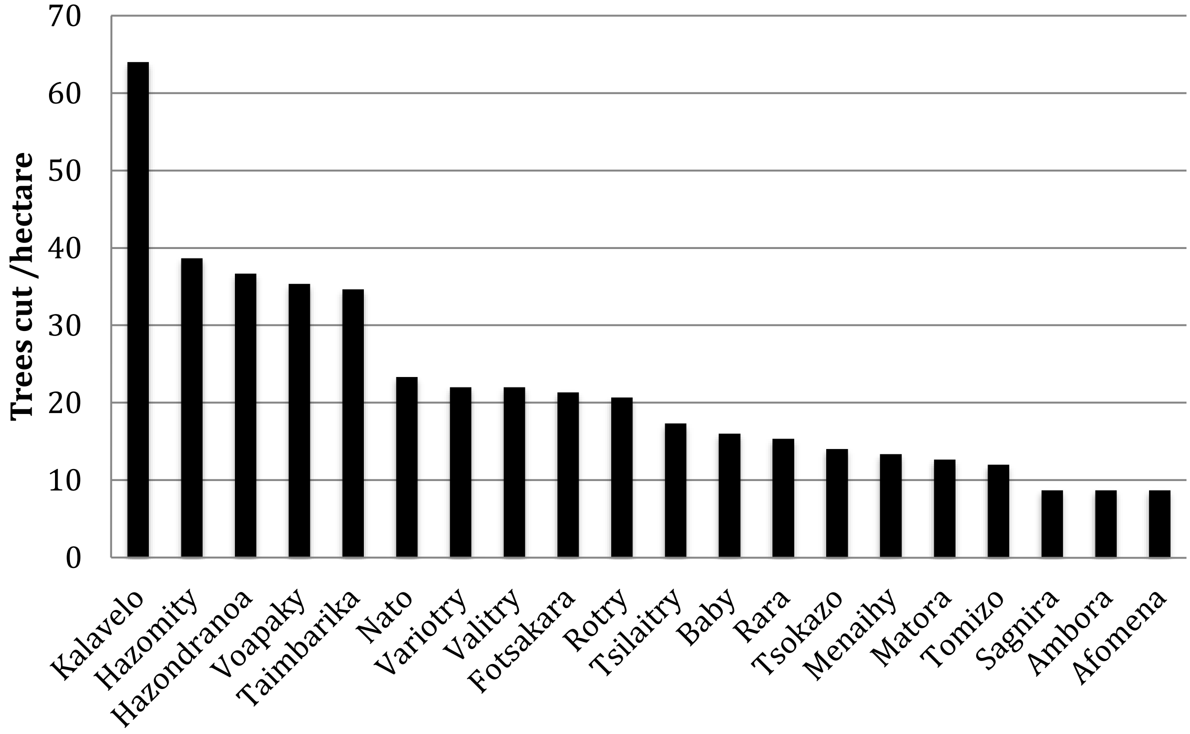
Figure 7: Size distribution of Aveotry (*Hartogiopsis trilobocarpa*)





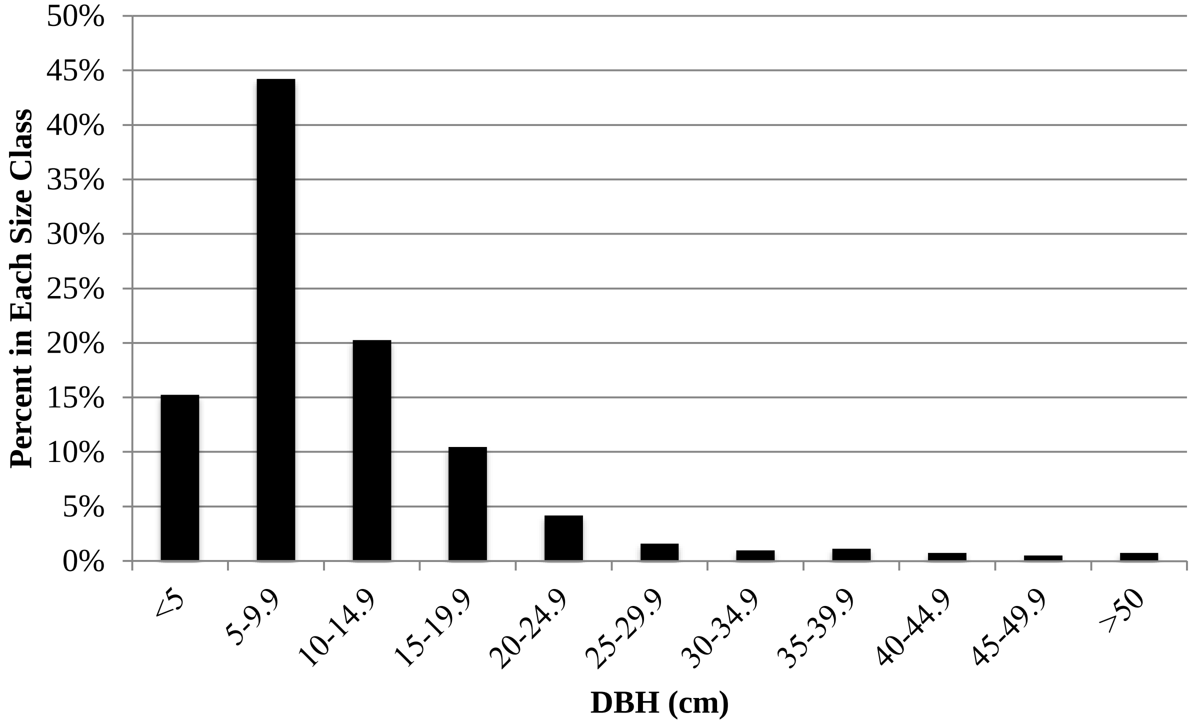
I found a total of 812 trees >3cm DBH cut within my study area. Extrapolating the density of cut trees found across 371 acres gives an estimate of 200835 trees cut annually. There were 61 species cut in addition to my 5 target species. By far the most frequently cut was Kalavelo (*Suregada sp.*) (Figure 8). Unfortunately, I have no information on the density or population size of these other species with which to assess the sustainability of their populations.

Figure 8: 20 must frequently cut species by vernacular names



On average cut trees had a diameter of 10.98 cm and the size distribution is much more even than among the most targeted species. However, this likely does not hold true for individual species. Certain species such as Habolatry were only found cut in the largest size classes whereas others were found in a broader range of size classes. Some, like Kalavelo and Hazondranoa, were heavily exploited in small size classes.

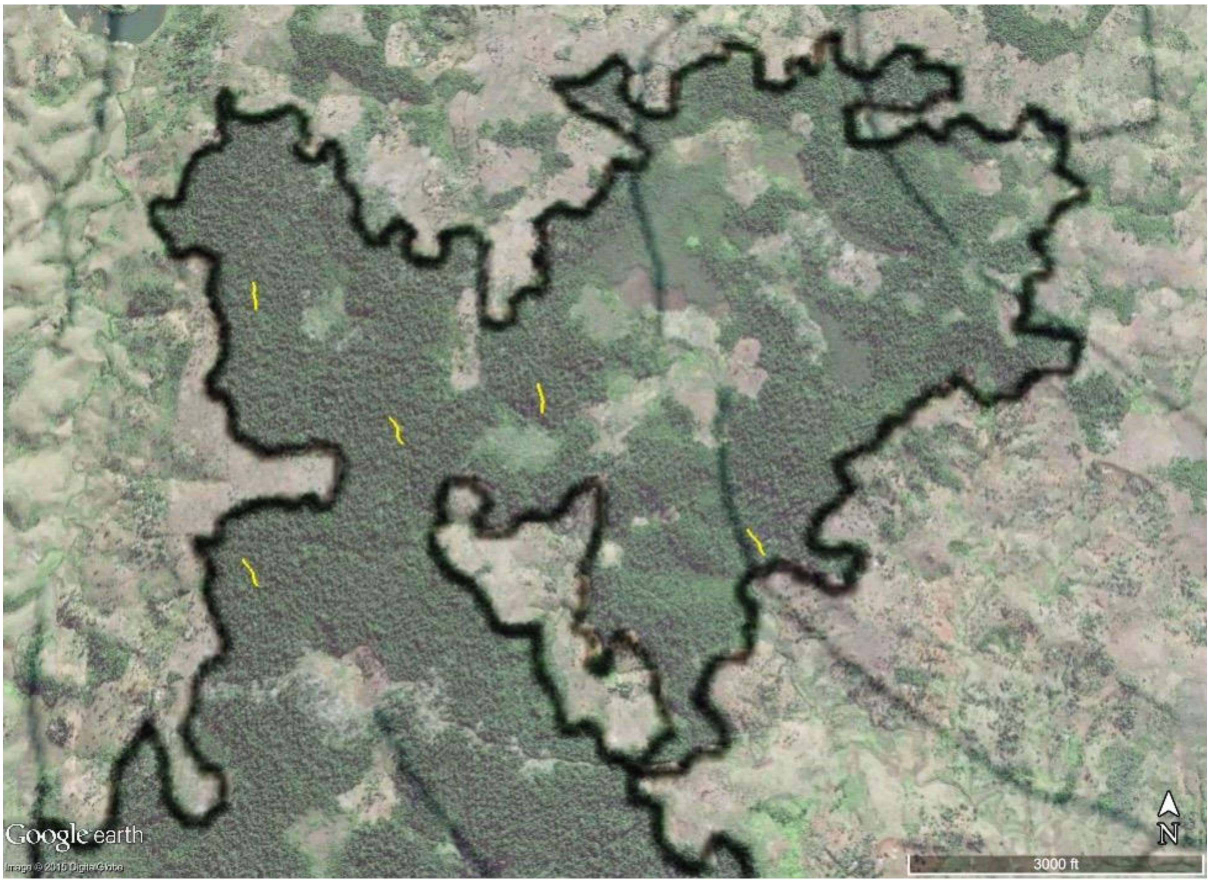
Figure 9: Size distribution across all species of trees cut in the past year



Discussion:

Unfortunately, I was not able to adequately assess the status of Lalo or Haziny populations. This is likely due to their ecology. According to my guides, both of these species tend to be limited to wetland or riparian areas and my plots were chosen for an even geographic distribution rather than a stratified sample of ecological conditions. Additionally, I do not know the extent to which proximity to water limits their distribution. Several of the Haziny and the single Lalo we found were not apparently located near water (see Figure 10). However, there may be groundwater in those areas that is not visible. These types of wetlands, if they exist, could be important hydrologically and ecologically and merit further research. With such a small sample of these two species, it is impossible to tell whether their rarity is a result of plot location or actual scarcity and it is likely that my results are not representative of the true densities of Lalo and Haziny. Nevertheless, their restricted habitat may put them at greater risk than trees growing in upland or both upland and riparian areas.

Figure 10: This image overlays a map of the streams (in blue) with the locations of the transects in which Haziny and Lalo are found.



For the other three species -Voapaky, Taimbarika, and Aveotry - current rates of cutting are not sustainable. Though more research needs to be done on the regrowth rates of these species, there is no way a loss of 40%, 29% or even 16% of a population in a single year is sustainable. Additionally, the size distributions shown in Figures 5, 6, and 7, show that prolonged overexploitation has devastated the older, larger trees of these three species and that trees less than 10 cm predominate, especially among Taimbarika and Voapaky. The rarity of large, mature individuals and intense pressure on trees as small as 5cm DBH could hinder the regeneration of these species. In order to predict and manage the future of Ankarabolava, we also need to collect data on the rates of regrowth of these trees and the size and health of the reproductive population.

The inventory of trees cut within the past year identifies several other key species for a more in-depth stock assessment, including 3 – Kalavelo (*Suregada sp*.), Hazomity (*Diospyros sp*.), and Hazondranoa (*Thecacoris sp*.) – cut in greater volumes than the any of the 5 species on which I focused. It would be interesting to know if these trees have similar economic value to the 5 species identified by Andrianantenaina or if they are less desirable, but being cut due to the increasing scarcity of the most valuable trees.

Within the sustainable use zone, permits are issued each year, allowing for a limited number of trees to be cut legally. Unfortunately I don’t have the exact number of permits for 2015, but the average permitted volume between 2011-2013 was 36670 trees, but my estimates put the number of trees cut in the past year close to 200835. This dramatic discrepancy demonstrates that illegal logging is a severe threat to the sustainability of Matanga’s forest.

Conclusion:

If current logging rates continue, the forest will disappear within the next generation or two. However, increased enforcement cannot be the only solution. Most of the people cutting wood illegally in Matanga are doing so to provide for their families. During the gap between harvests, sale of wood is the principle source of revenue for some households. The future management success of Ankarabolava hinges on the provision of economic alternatives and a better understanding of the resources that exist in the forest.

In order to better understand and manage the forest, there must be a more complete stock assessment of all types of useful wood. It would also be useful to study the stock of individuals suitable for sale because many individuals are bent or have irregularities that would make them difficult to use in construction. This assessment should also take advantage of local knowledge and involve some sort of participatory research with the forest police officers and woodcutters about preferred species, vernacular names, rarity, patterns of distribution, and any ecological or habitat characteristics. These should then be corroborated with scientific studies, but could help improve experimental design for future projects and would be a great opportunity for raising local awareness and involvement. Ideally, there should also be consistent long-term monitoring of plant populations to evaluate management and better understand long-term trends.

There are no easy solutions to the problem of selective cutting in Ankarabolava, but the forest is too important to the livelihoods of local people and to the preservation of global biodiversity to be allowed to disappear. There are a number of steps that can be taken to reduce pressure on the forest. These include educating the community about the future of the forest and the impacts its loss will have on their lives as well as training woodcutters in more efficient and less wasteful techniques. Throughout the study, we saw wasted wood where trees were cut at waist or shoulder height or where trees were cut and abandoned. However, these actions will do little to slow the destruction of this Ankarabolava without the provision of viable economic alternatives for those who make their living from the forest.

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Appendix I: Species and Habitat Images

Figure I.1: Intensively logged part of a transect

Figure I.2: Typical less disturbed habitat

Figure II.3: Voapaky aerial roots

Figure I.4: Voapaky leaves

Figure I.5: Characteristic yellow resin of Haziny

Figure I.6: Characteristic branching pattern of Haziny

Figure I.7: Taimbarika leaves

Figure I.8: Taimbarika leaves underside

Figure I.9: Aveotry

Figure I.10: Lalo

Appendix II: Vernacular and Scientific Names

Vernacular Name	Scientific Name
Afkalalao	Unknown 1
Afomena	Dombeya elliptica
Ambora	Tambourissa purpurea
Andriamena	Psorospermum chionanthifolium
Atsebo/Hatsebo	Protium madagascariensis
Aveotry	Hartogiopsis trilobocarpa
Baby	Anthostema madagascariensis
Fanagnara	Unknown 2
Fatsinakoho/Fantsinakoho	Carissa edulis
Fosakatry/Fotsiakatry	Pyranthus sp.
Fosivogny/Fotsivony	Aphloia sp.
Fotsakara/Fotsiakara	Homalium sp.
Habolatry	Unknown 3
Hafitry	Unknown 4
Haronga/Harongana	Harungana madagascariensis
Harongapanihy	Croton nitidulus
Haziny	Symphonia fasciculata
Hazoindranoa/Hazondranoa	Thecacoris sp.
Hazomasy	Anisophyllea fallax
Hazomity	Diospyros sp.
Hazondambo	Gaertnera macrostipula
Hitsy	Intsia bijuga
Kabokala	Coffea sp.
Kafenala	Coffea sp.
Kalavelo	Suregada sp.
Komanongo/komorongy	Mauloutchia sp.
Lalo	Weinmannia venusta
Marapotiny/Maroampotony	Homalium sp.
Matora	Vitex chrysomallum
Menaihy/Menahy	Cleistanthopsis sp.
Mokarana	Macaranga macropoda
Monoky/Manoky	Craspidospermum verticillatum
Nato	Unknown 5
Natoboaky	Faucherea sp.
Palimara/Apalimara	Ambalis sp.
Ramikallaloa	Unknown 6
Rara	Mauloutchia sp.
Ravinovy	Bathiohamnus sp.
Reheky	Chrysophyllum boivinianum
Retsiriky	Phyllarthron sp.
Rotry	Syzigium sp.

Sagnira	Unknown 7
Sakonala/sakoanala	Euphorbia sp.
Taimbarika/Taimbariky	Cleisthanthus sp.
Tamenaky	Polyalthia richardiano
Tandrikosy/Tandrokosy	Petchia madagascarensis
Tarata	Abrahamia sericea
Tomizo	Eugenia sp.
Tsilaidomo	Homalium sp.
Tsilaidoza	Vitex sp.
Tsilaitry	Diospyros sp.
Tsinditrafo	Schizolaena sp.
Tsipopoky	Majidea sp.
Tsiramy	Canarium sp.
Tsitoto/Tsitohitohy	Oncostemum sp.
Tsokazo	Unknown 8
Tsombotsohy/Tsongotsohy	Colea sp.
Valitry	Breonia sp.
Variotry	Cynometra sp.
Varongy	Ocotea racemosa
Vasingiry	Cryptocarpa acuminata
Vatsila	Polyscias lancifolia
Vatsilambato	Astrotrichilia/ Poupartia sp.
Vilo	Paropsia edulis
Vimboa	Dalbergia sp.
Voapaky/Vopaky	Uapaca littoralis

*Scientific names obtained from Rasolondraibe 2010

Appendix III: Number and average DBH of each species cut in the past year throughout all transects

Vernacular name	Total found	Average DBH
Afkalalao	1	23.1
Afomena	13	6.3
Ambora	13	11.3
Andriamena	1	5.3
Atsebo/Hatsebo	4	25.7
Aveotry	11	12.9
Baby	24	11.6
Fanagnara	8	8.7
Fatsinakoho/Fantsinakoho	3	10.8
Fosakatry/Fotsiakatry	2	8.1
Fosivogny/Fotsivony	9	12.5
Fotsakara	32	12.7
Habolatry	9	44.2
Hafitry	3	7.4
Haronga/Harongana	2	17.4
Harongapanihy	3	6.2
Haziny	1	17.8
Hazomasy	2	5.3
Hazomity	57	10.9
Hazondambo	9	6.9
Hazondranoa	55	7.5
Hitsy	1	5.0
Kabokala	2	9.2
Kafenala	4	12.4
Kalavelo	95	8.1
Komanongo/Komorongy	1	4.0
Lalo	1	15.5
Marapotiny/Maroampotony	2	9.1
Matora	19	13.3
Menaihy	20	7.0
Mokarana	11	7.4
Monoky/Manoky	1	40.0
Nato	35	13.6
Natoboaky	4	15.2
Palimara/Apalimara	4	10.7
Ramikallaloa	4	14.0
Rara	23	14.6
Ravinovy	1	35.5
Reheky	11	11.7
Retsiriky	1	4.5
Rotry	29	15.1

Sagnira	13	15.4
Sakonala/Sakoanala	1	32.1
Taimbarika	50	7.0
Tamenaky	5	13.0
Tandrikosy/Tandrokosy	1	5.0
Tarata	1	36.2
Tomizo	18	7.7
Tsilaidomo	2	7.8
Tsilaidoza	1	6.7
Tsilaitry	26	7.2
Tsinditrafo	4	7.0
Tsipopoky	1	15.5
Tsiramy	1	19.2
Tsitoto/Tsitohitohy	2	23.5
Tsokazo	21	16.1
Tsombotsohy/Tsongotsohy	7	10.4
Valitry	33	12.3
Variotry	33	8.0
Varongy	6	13.0
Vasingiry	4	7.2
Vatsila	4	13.8
Vatsilambato	1	8.0
Vilo	1	5.4
Vimboa	4	10.4
Voapaky	3	50.7
Voapaky/Vopaky	40	8.9

Appendix IV: Plot locations

Transect	Start		End	
	Latitude	Longitude	Latitude	Longitude
T1	-23.51398	47.50141	-23.51313	47.50119
T2	-23.51058	47.50404	-23.50984	47.50353
T3	-23.50526	47.50991	-23.50461	47.5094
T4	-23.49992	47.50703	-23.49909	47.50676
T5	-23.51273	47.4921	-23.51198	47.49131
T6	-23.51377	47.48873	-23.513	47.48829
T7	-23.50332	47.48768	-23.50241	47.48749
T8	-23.50703	47.48869	-23.50627	47.4883
T9	-23.50741	47.49263	-23.50665	47.49216
T10	-23.50643	47.49701	-23.50556	47.49687
T11	-23.50011	47.48677	-23.49925	47.48669
T12	-23.50466	47.49214	-23.50388	47.49183
T13	-23.51154	47.4884	-23.51078	47.48791
T14	-23.50705	47.50532	-23.50617	47.50512
T15	-23.5142	47.49541	-23.51355	47.49489

Appendix V: Count per plot

Plot #	# cut	Voapaky total	Voapaky living	Voapaky cut	Taimbarika total	Taimbarika living	Taimbarika cut	Aveotry total	Aveotry living	Aveotry cut	Haziny total	Haziny living	Haziny cut	Lalo total	Lalo living	Lalo cut
1	88	15	10	5	9	6	3	0	0	0	0	0	0	0	0	0
2	43	30	14	16	3	3	0	5	2	3	1	1	0	0	0	0
3	50	5	3	2	15	9	6	3	2	1	0	0	0	0	0	0
4	53	5	5	0	29	22	7	2	1	1	0	0	0	0	0	0
5	62	0	0	0	21	19	2	9	8	1	0	0	0	0	0	0
6	24	1	1	0	8	7	1	1	0	1	0	0	0	0	0	0
7	48	19	4	15	48	43	5	0	0	0	0	0	0	1	0	1
8	34	0	0	0	36	36	0	1	1	0	0	0	0	0	0	0
9	48	5	4	1	31	28	3	3	2	1	1	1	0	0	0	0
10	49	17	15	2	17	14	3	0	0	0	1	1	0	0	0	0
11	57	10	4	6	12	8	4	4	3	1	0	0	0	0	0	0
12	43	4	4	0	39	35	4	1	0	1	0	0	0	0	0	0
13	76	7	5	2	15	11	4	6	6	0	1	0	1	0	0	0
14	87	5	2	3	21	15	6	2	1	1	0	0	0	0	0	0
15	50	8	7	1	15	11	4	1	1	0	0	0	0	0	0	0
Total	812	131	78	53	319	267	52	38	27	11	4	3	1	1	0	1
Avg.	54.1	8.7	5.2	3.5	21.3	17.8	3.5	2.5	1.8	0.73	0.27	0.2	0.07	0.07	0	0.07
St. Dev.	17.9	8.3	4.6	5.2	12.8	12.4	2.1	2.6	2.3	0.80	0.46	0.41	0.26	0.26	0	0.26
Indiv / ha	541	87	52	35	213	178	35	25	18	7	2.6	2	0.67	0.67	0	0.67
Est. Pop.	200835	32401	19292	13109	78899	66038	12861	9399	6678	2721	989	742	247	247	0	247